NASA Technical Memorandum 72864

FLIGHT TEST EVALUATION OF AN RAF HIGH ALTITUDE PARTIAL PRESSURE PROTECTIVE ASSEMBLY

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INTRODUCTION

The flight test program on the F-15 aircraft at the NASA Dryden Flight Research Center (DFRC) requires flights to altitudes between 15,240 meters (50,000 feet) and 18,288 meters (60,000 feet). High altitude protection equipment is required for pilot safety at such altitudes in the event of a loss of cabin pressurization. A full pressure suit has been the only high altitude garment in use at DFRC.

The Center pilots have reservations about the use of full pressure suits, because the helmet, the neck ring, and their combination reduce the pilot's field of vision and the gloves reduce the hand and finger dexterity. The bulk of the helmet, gloves and glove rings also reduces the pilot's dexterity. Further, the provisions for suit ventilation in the F-15 are inadequate. The resulting loss in pilot effectiveness therefore creates pilot fatigue and reduces the mission effectiveness.

The British Royal Air Force (RAF) partial pressure jerkin suit (fig. 1) was chosen as an alternative to the full pressure suit to protect the pilots during rapid descent in case of cabin pressurization loss. In the 4 years before 1976, some 200 RAF and Royal Navy (RN) aircrew used the pressure jerkin within its stated altitude envelope (fig. 2). The total RAF experience with the jerkin for various altitude envelopes (app. I) spans 15 years. In addition, the RAF pressure jerkin can be combined with an RAF type P/Q oxygen mask, a standard helmet, and an anti-g suit; all of these have the advantage of rapid unaided donning.

Figure 1. Pressure jerkin and dual bladder anti-g suit trousers.

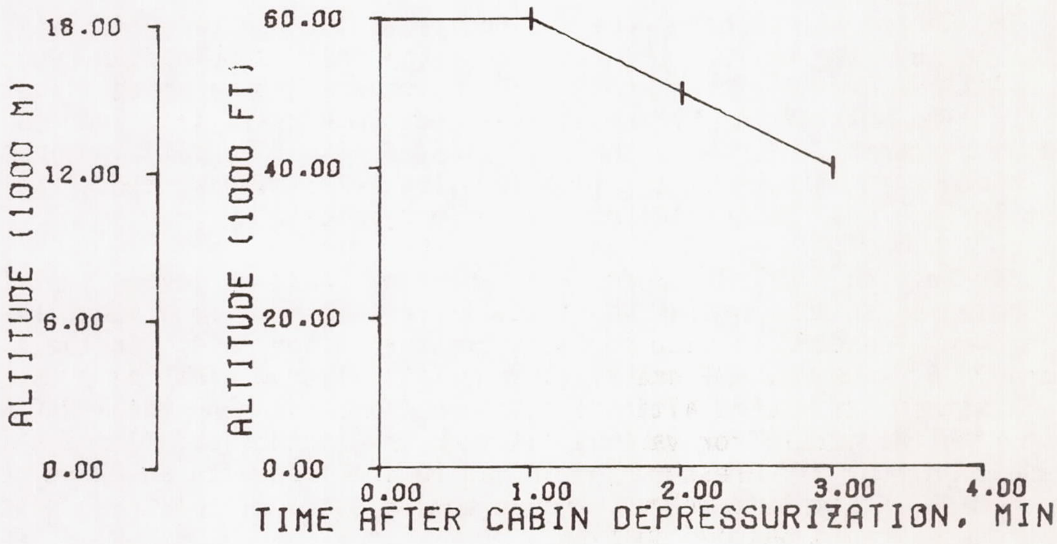

Figure 2. Jerkin altitude envelope.

Preliminary training and experience with the jerkin and P/Q mask were afforded DFRC personnel during a trip to the RAF's Institute of Aviation Medicine, Farnborough, Hantshire, England. The hardware, consisting of the partial pressure jerkin suit, P/Q mask, and dual bladder g-suit (fig. 1), provides short term protection at aircraft altitudes up to 18,288 meters (60,000 feet) provided the aircraft descent is within the jerkin altitude envelope. The breathing pressures are somewhat lower than required for continous operation at 18,288 meters (60,000 feet) but are sufficient to allow a pilot to perform the descent within the time periods defined by the jerkin altitude envelope. The profile of descent time specified by the jerkin altitude envelope exceeds the emergency descent requirements of either the F-104 or F-15.

Joint testing of the jerkin was conducted by the NASA Dryden Flight Research Center and the USAF School of Aerospace Medicine (app. II). The results of a laboratory evaluation and the testing during jerkin training for NASA pilots gave both the pilots and ground support personnel confidence in the equipment. Altitude chamber testing was performed to obtain an evaluation of the equipment from test subjects in addition to the NASA pilots prior to flight tests. The chamber test subjects stated that there was a definite training effect and a resultant enhanced performance at altitude.

Two pressure clothing assemblies were obtained from RAF (app. I) and are identified as 1) pressure jerkin and anti-g trousers and 2) combined partial pressure, anti-g and ventilated coverall garment. The first assembly has undergone all the testing and is the subject of this report. The second assembly has not, as yet, undergone flight testing at DFRC. The pilots preferred the pressure jerkin because it can be donned at the aircraft and minimizes thermal buildup (app III).

SYMBOLS AND ABBREVIATIONS

DFRC	Hugh L. Dryden Flight Research Center
h_a	F-104 aircraft pressure altitude
h_c	F-104 cabin pressure altitude
HC	F-15 computed cabin altitude
HP	F-15 geopotential altitude
mm Hg	millimeters of mercury
NASA	National Aeronautics and Space Administration
P/Q	large/small pressure demand oronasal mask
RAF	British Royal Air Force

RN British Royal Navy

α angle of attack (free stream)

EQUIPMENT

The pressure jerkin, dual bladder anti-g suit, miniaturized man mounted oxygen regulator, and P/Q pressure demand oronasal mask are shown in figures 1 and 3. The jerkin is a torso garment consisting of a single oxygen bladder which applies a pressure to the entire trunk. The jerkin bladder is pressurized by the breathing oxygen regulator through a valve in the hose to the mask. The breathing regulator has a pressure output proportional to the aircraft's cabin altitude, as shown in figure 4. The jerkin oxygen bladder valve prevents oxygen flow from the bladder to the mask. At the maximum altitude for the jerkin, the output of the regulator is specified to be 68 mm Hg (1.31 psi) to 72 mm Hg (1.39 psi).

The jerkin and anti-g suit are worn as the outermost garment and can be donned at the aircraft to delay thermal buildup and doffed directly after the flight. Both garments are shown in figure 5 installed on a manikin with torso harness in the F-15 seat. The type P/Q oxygen mask and its chain suspension harness are shown donned in figure 6.

The anti-g suit shown in figure 1 consists of trousers with two bladders and two inlet hoses. One inlet hose provides a pressure connection from the oxygen regulator, and the other hose provides a connection to the barometric anti-g valve. The barometric valve responds to a positive g-load or a fall in cabin pressure. The breathing oxygen supply line provides oxygen at a pressure of 4.92 kilograms per square centimeter (70 psi), a pressure that is standard for the anti-g suit valve in both the F-15 and F-104; therefore no modifications were necessary for testing in either aircraft.

The P/Q type oronasal mask is designed with a reflected edge seal (fig. 7), which can deliver pressures up to 100 mm Hg (1.93 psi) to the respiratory tract without serious leakage. The mask is attached to the pilot's chain harness, which utilizes two tension configurations. The pilot manually operates the tension to the high setting when cabin depressurization occurs. The chain tension is returned to the low setting when mask leakage is not a problem. The mask covers the nose and mouth and rests on the anterior portion of the chin, as shown in figures 6 and 7, rather than under the chin. The pilots preferred this mask, since it did not rotate down and under the chin during g-loading as those masks currently in use tend to do (app. III). The mask includes a microphone that is compatible to DRFC aircraft radios.

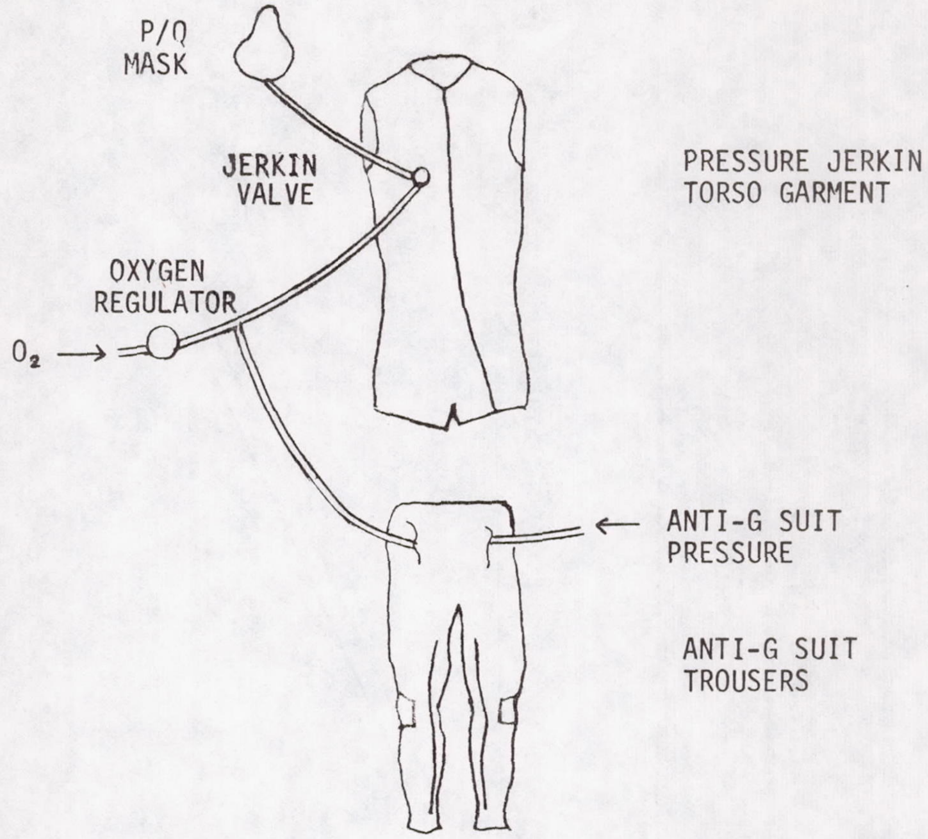

Figure 3. Schematic of pressure jerkin, mask and dual bladder anti-g suit.

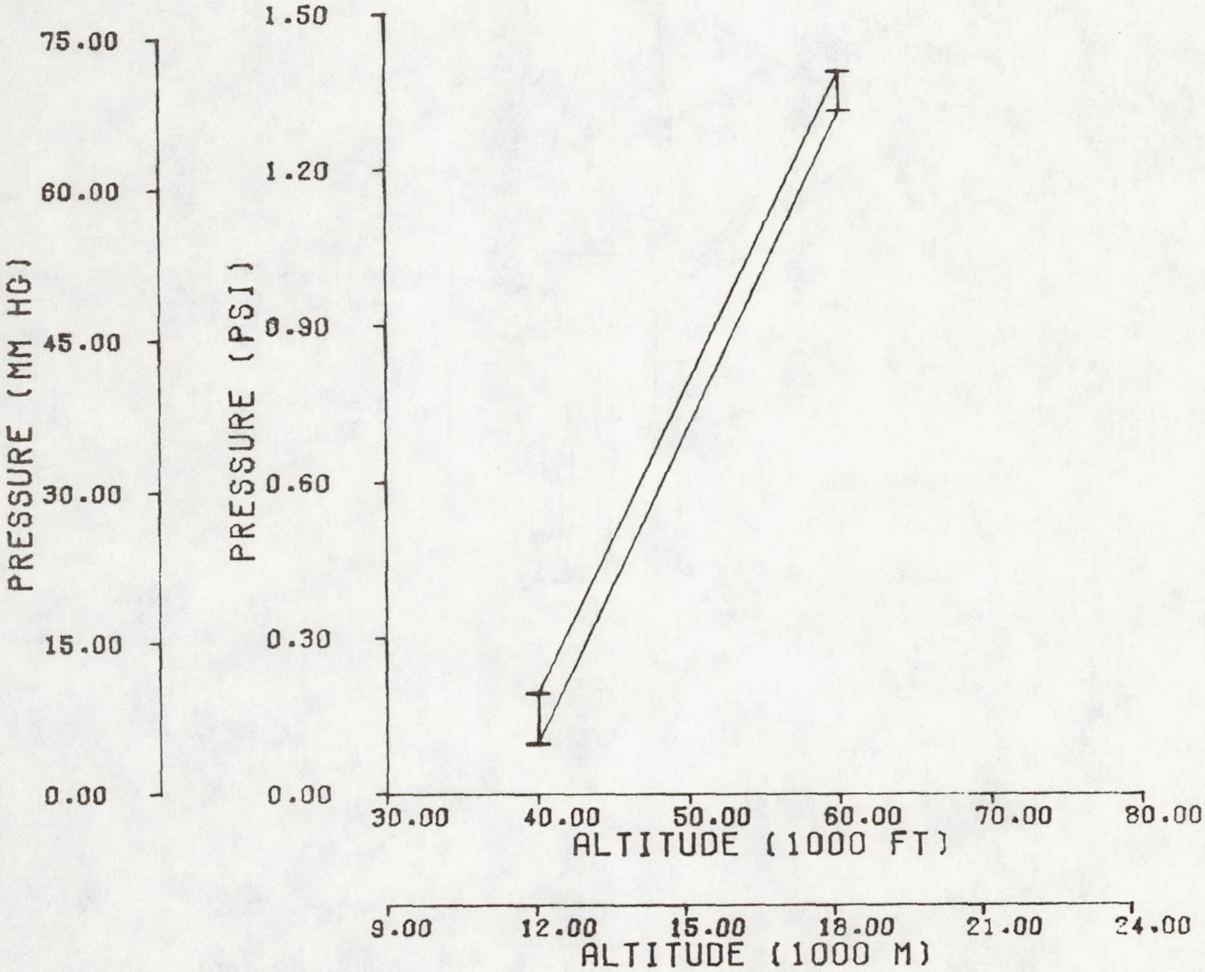

Figure 4. Breathing regulator envelope.

Figure 5. Pressure jerkin and anti-g suit in F-15 seat.

Figure 6. RAF type oxygen mask and chain harness.

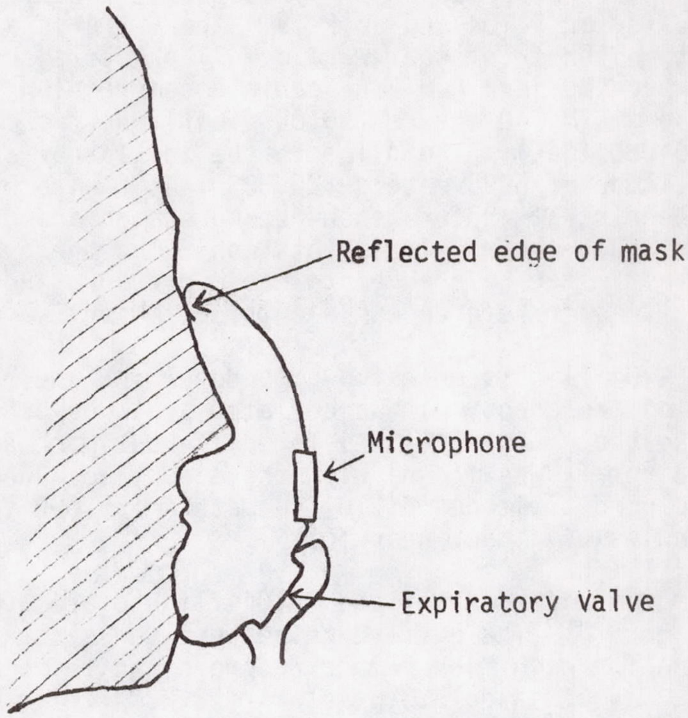

Figure 7. Principle of sealing for RAF oronasal mask.

FLIGHT TESTING

Flight tests were performed on the pressure jerkin at the Dryden Flight Research Center using an F-104 and an F-15. The F-104 is a two-seater aircraft. The pilot in the front seat wore a full pressure suit, and the pilot in the aft seat wore the jerkin. Four cabin decompressions were performed, two at an altitude of 15,240 meters (50,000 feet) and two at an altitude of 18,288 meters (60,000 feet). The pilot in the jerkin performed each aircraft descent to an altitude of 6096 meters (20,000 feet). The pilot in the jerkin had control of the aircraft before each decompression and did not know when the decompression would occur. The pilots monitored the cabin pressure altitude with an altimeter referenced to cabin pressure and flew the aircraft altitude via an altimeter referenced to outside ambient.

Additional F-104 flights were flown to determine whether the effect of aerodynamic flow on the canopy with a deflated seal would decrease the cabin pressure (increase the cabin altitude) for different Mach numbers and angles of attack. The aircraft was flown, with the canopy seal deflated, through a profile which included altitudes of 16,764 meters (55,000 feet), Mach numbers up to 1.8, and angles of attack near 10^{0}.

The tabulated data for one of the F-104 flights are presented in table 1 and plotted in figure 8. The difference between the aircraft altitude and the cabin altitude for each Mach number recorded can be seen. The greatest difference is at Mach 1.3 and 15,316 meters (50,250 feet), where the cabin altitude exceeds that of the aircraft by 518 meters (1700 feet).

Figure 9 shows the difference between the cabin pressure altitude and the actual aircraft pressure altitude (H-cabin - H-aircraft) as a function of aircraft altitude. The Mach number for each data point is also shown. The aircraft's angle of attack (α) was recorded at four data points to determine whether the aerodynamic slipstream for different angles of attack would change the cabin pressure altitude. Figure 9 shows that cabin altitude increased for a nearly constant aircraft altitude of approximately 16,764 meters (55,000 feet) as angle of attack increased. The increase in the discrepancy between cabin and aircraft altitude at a Mach number of 1.8 for a change in angle of attack from 5.0^{0} to 9.5^{0} is 76.2 meters (250 feet). The increase at Mach 1.5 for an angle of attack change from 5.8^{0} to 10.1^{0} is 122 meters (400 feet).

These tests demonstrated the performance, feasibility, and safety of the pressure jerkin in the flight environment. The pilots were able to perform all tasks required to operate the pressure jerkin and fly the aircraft through the prescribed descent profile with almost total satisfaction (app. III). Therefore, the jerkin evaluation was continued in a single-seat F-15. DFRC's F-15 is a fully instrumented flight test aircraft and the parameters shown in table 2 were recorded during the tests. The data document a cabin decompression at an altitude of 16,764 meters (55,000 feet)

and are plotted in figure 10 as a time history along with the F-15's geopotential altitude (HP), Mach number, and angle of attack.

The F-15 was flown in level flight near an altitude of 16,764 meters (55,000 feet) and Mach 1.4 prior to cabin depressurization. As a result of depressurization, the cabin pressure went from 346 mm Hg (6.7 psi), which represents an altitude of 6142 meters (20,150 feet), to 77 mm Hg (1.49 psi) or 16,301 meters (53,480 feet) in approximately 11 seconds. The cabin pressure altitude (HC) was computed from the cabin pressure data listed in table 2. Tabular values for geopotential altitude versus pressure were obtained from reference 1. Interpolated values were then computed for the cabin pressure data during depressurization and are listed in table 3. Mach number was held near 1.5, while angle of attack was increased to 9^0, which resulted in a small increase in cabin pressure (to 78 mm Hg (1.51 psi), which is equivalent to a pressure altitude of 15,921 meters (52,234 feet)). The difference between aircraft geopotential and cabin pressure altitude is 840 meters (2755 feet), as shown in table 3. The tabular data for the geopotential altitude minus the cabin pressure altitude (HP-HC) show the cabin altitude to be less than the aircraft altitude for any given combination of Mach number and angle of attack. The same can be stated for the nose boom altitude minus the cabin altitude except near Mach 1, where the nose boom data become less reliable. The difference between the geopotential and nose boom altitudes varies from 9 to 23 meters (30 to 75 feet). Unlike the F-104, the difference in the cabin and aircraft ambient altitude for the F-15 results in a lower cabin altitude (higher cabin pressure) than the aircraft ambient altitude.

The tabular data for HP-HC are plotted as a time history in figure 11. The greatest difference in pressures occurs for the high angles of attack (9.0^0 and 10.6^0) at Mach numbers above 1.2. The highest angle of attack (13.3^0) was flown at a Mach number of 1.13 and resulted in a simular difference in HP-HC, but occurred from a lower baseline, showing the difference to be a function of both Mach number and angle of attack. The reason that the cabin altitude decreased as compared with the ambient altitude is believed to be the aerodynamics of the F-15, which have a greater ram air effect than with the F-104. At high angles of attack, the F-15 exhibited even greater reductions in cabin altitude during depressurizations. Therefore, during an emergency loss of the canopy seal, the pilot in the F-15 could expect a higher cabin pressure (lower cabin altitude) than his indicated altitude. Safety aspects therefore favor the F-15 as the test aircraft due to lower than indicated altitude exposure.

After the F-104 and F-15 tests, the pilots reported hand dexterity and pilot field of vision to be the same as when wearing a flying suit, mobility in the cabin to be unimpeded, and ease of donning to be excellent. The only drawback reported was the heat buildup due to wearing both the jerkin and the anti-g trousers. This reportedly was not intolerable and was considered preferable to the disadvantages of wearing a full pressure suit (app. III).

The pressure jerkin was therefore adopted as an operational suit (for

TABLE 1. F-104 JERKIN SUIT TEST

(ENVIRONMENTAL CONTROL SYSTEM OFF, RAM AIR CLOSED)

MACH NUMBER	AIRCRAFT ALTITUDE (FEET)	CABIN ALTITUDE (FEET)	ANGLE OF ATTACK (DEGREES)
1.2	34200	35000	----
1.3	34050	34700	----
1.4	34100	34200	----
1.5	34050	33900	----
1.6	36500	36400	----
1.7	42700	43000	----
1.8	46000	46400	----
1.8	50000	50000	----
1.8	54850	55100	5.
1.8	54600	55100	9.5
1.5	54700	55600	5.8
1.5	54500	55800	10.1
1.3	50250	51950	----
1.2	50300	51900	----
1.1	50350	52000	----
1.0	50400	50900	----
1.0	49600	50900	----

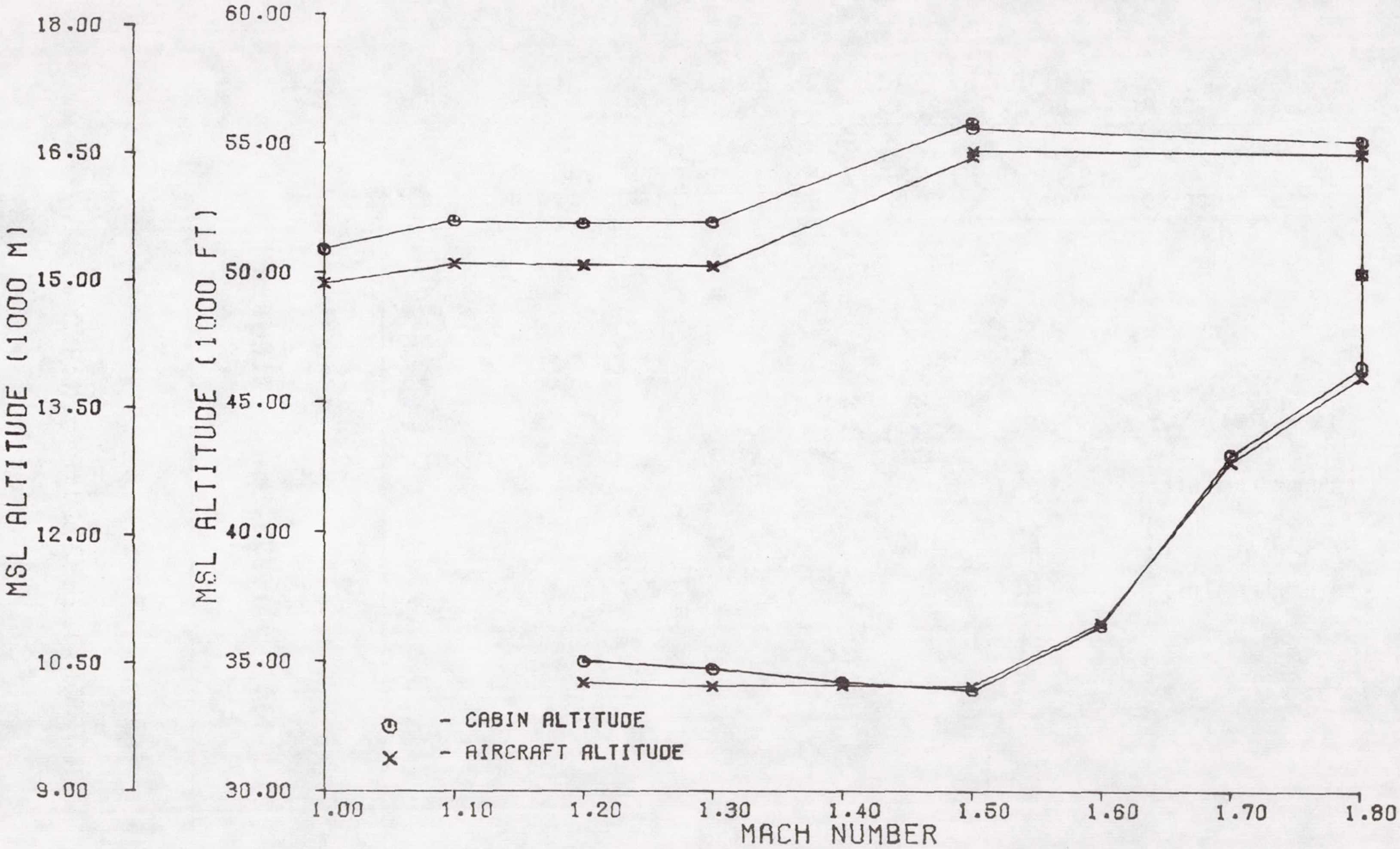

Figure 8. F-104 cabin altitude as a function of Mach number and aircraft altitude.

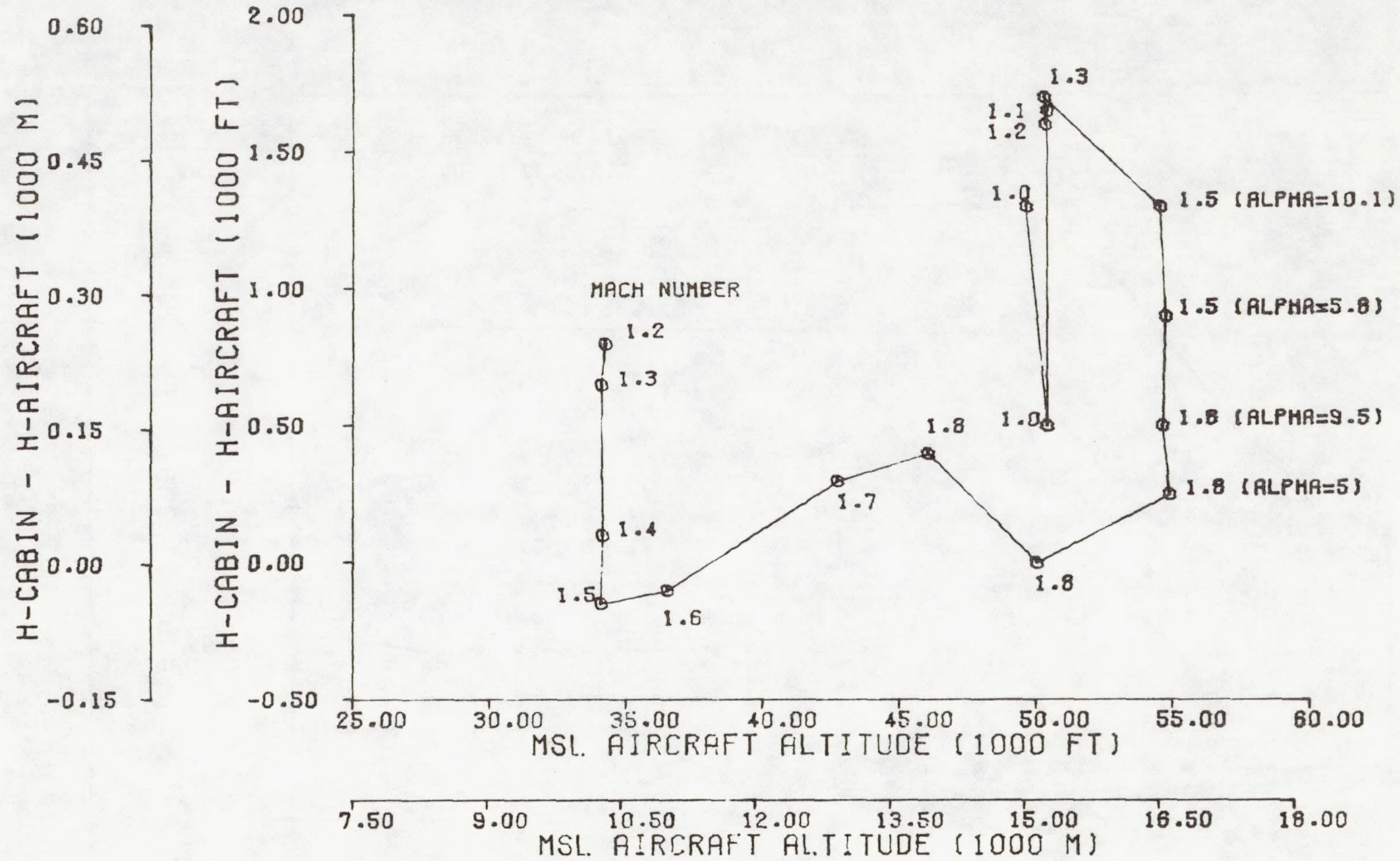

Figure 9. F-104 elevated cabin altitude as a function of aircraft altitude and Mach number.

TABLE 2. F-15 JERKIN SUIT TEST

TIME CODE	CABIN PRESSURE (PSI)	NOSE BOOM ALTITUDE (FEET)	GEOPOTENTIAL ALTITUDE HP (FEET)	MACH NUMBER	ANGLE OF ATTACK (DEGREES)
13-52-30- 0	6.6880	54577	54626	1.4500	.3882
13-52-35- 0	6.7013	54902	54949	1.4633	3.1610
13-52-40- 0	6.6413	55158	55203	1.4725	1.7168
13-52-45- 0	6.7063	55115	55158	1.4853	3.6369
13-52-50- 0	6.6980	55102	55143	1.4932	2.4791
13-52-55- 0	6.6972	55054	55094	1.4999	3.1715
13-53- 0- 0	6.4974	55059	55097	1.5089	2.9426
13-53- 5- 0	4.5753	55006	55042	1.5212	2.9445
13-53-10- 0	1.6374	54946	54981	1.5310	2.9460
13-53-15- 0	1.4764	54950	54983	1.5364	2.4947
13-53-20- 0	1.4749	54950	54982	1.5429	2.4862
13-53-25- 0	1.4719	54856	54886	1.5537	3.9001
13-53-29-800	1.5107	54955	54989	1.5347	8.9783
13-53-30- 0	1.4636	55069	55103	1.5238	8.7478
13-53-35- 0	1.4314	55571	55608	1.5172	3.2123
13-53-40- 0	1.4336	55662	55699	1.5181	2.7229
13-53-45- 0	1.4201	55605	55643	1.5100	3.6436
13-53-50- 0	1.4448	55652	55694	1.4923	3.1886
13-53-55- 0	1.4006	55674	55716	1.4853	2.2474
13-54- 0- 0	1.4523	55479	55525	1.4689	4.0485
13-54- 5- 0	1.4559	55335	55384	1.4501	3.6055
13-54-10- 0	1.4559	55216	55267	1.4362	3.5907
13-54-15- 0	1.4409	55087	55142	1.4165	5.1724
13-54-20- 0	1.4746	55092	55151	1.3860	4.7370
13-54-25- 0	1.4701	55187	55249	1.3579	5.8552
13-54-29-200	1.4866	55330	55398	1.3047	10.6430
13-54-30- 0	1.4469	55330	55398	1.2961	6.9515
13-54-35- 0	1.4439	55445	55515	1.2779	3.7723
13-54-40- 0	1.4424	55459	55530	1.2661	4.2412
13-54-45- 0	1.4124	55454	55527	1.2461	4.2348
13-54-50- 0	1.4094	55435	55509	1.2366	4.4448
13-54-55- 0	1.4049	55403	55478	1.2210	4.2268
13-55- 0- 0	1.4019	55440	55516	1.1808	11.9720
13-55- 0-500	1.4386	55459	55534	1.1701	12.3530
13-55- 2-100	1.4371	55513	55586	1.1328	13.2690
13-55- 5- 0	1.4004	55396	55467	1.0958	5.6654
13-55-10- 0	1.4401	54847	54917	1.0875	7.1269
13-55-15- 0	1.4446	54577	54645	1.0760	6.0047
13-55-20- 0	1.4521	54536	54602	1.0582	5.0406
13-55-25- 0	1.4866	54600	54663	1.0360	5.3279
13-55-30- 0	1.4319	53259	54509	1.0005	5.0776
13-55-35- 0	1.4538	53668	54784	.9858	3.9812
13-55-40- 0	1.7283	53796	54838	.9826	4.7163
13-55-45- 0	1.9506	53486	54723	.9991	3.7906
13-55-50- 0	2.2035	53143	54266	.9868	6.2846
13-55-55- 0	2.5328	52536	53789	1.0008	5.8214
13-56- 0- 0	2.9951	52105	53271	.9916	5.8450
13-56- 5- 0	3.5100	51999	53055	.9774	5.1708
13-56-10- 0	4.0143	51597	52641	.9756	5.1579
13-56-15- 0	4.5613	51144	52219	.9803	5.6178
13-56-20- 0	5.1375	50651	51711	.9781	5.6347
13-56-25- 0	5.7659	50216	51216	.9673	4.7002
13-56-30- 0	6.4124	49751	50680	.9522	6.2926
13-56-35- 0	6.8651	49305	50218	.9487	5.8606
13-56-40- 0	6.9191	48980	49841	.9369	6.1137
13-56-45- 0	6.9311	48687	49518	.9295	5.7007
13-56-50- 0	6.9229	48461	49229	.9130	5.4756
13-56-55- 0	6.9102	48238	48971	.9025	6.1666
13-57- 0- 0	6.9327	48004	48722	.8976	5.4588
13-57- 5- 0	6.9927	47737	48421	.8861	5.5323
13-57-10- 0	6.9957	47354	48009	.8756	5.9644
13-57-15- 0	7.0669	46843	47520	.8840	5.7459
13-57-20- 0	7.1208	46321	46975	.8752	6.2413
13-57-25- 0	7.1695	45793	46411	.8598	5.9619
13-57-30- 0	7.2145	45193	45829	.8676	5.7767
13-57-35- 0	7.2886	44581	45234	.8748	5.9651
13-57-40- 0	7.3336	44045	44698	.8747	5.7540
13-57-45- 0	7.3861	43520	44185	.8798	5.3579
13-57-50- 0	7.4431	43017	43669	.8743	5.3300
13-57-55- 0	7.4454	42511	43152	.8696	4.8596
13-58- 0- 0	7.5405	42047	42686	.8692	4.5485
13-58- 5- 0	7.5594	41682	42291	.8561	4.3437
13-58-10- 0	7.5902	41292	41874	.8448	2.8774
13-58-15- 0	7.6600	40731	41304	.8406	3.1281
13-58-20- 0	7.7491	40017	40583	.8374	3.8774
13-58-25- 0	7.8893	39225	39792	.8380	3.6114
13-58-30- 0	7.9492	38357	38951	.8493	3.6235

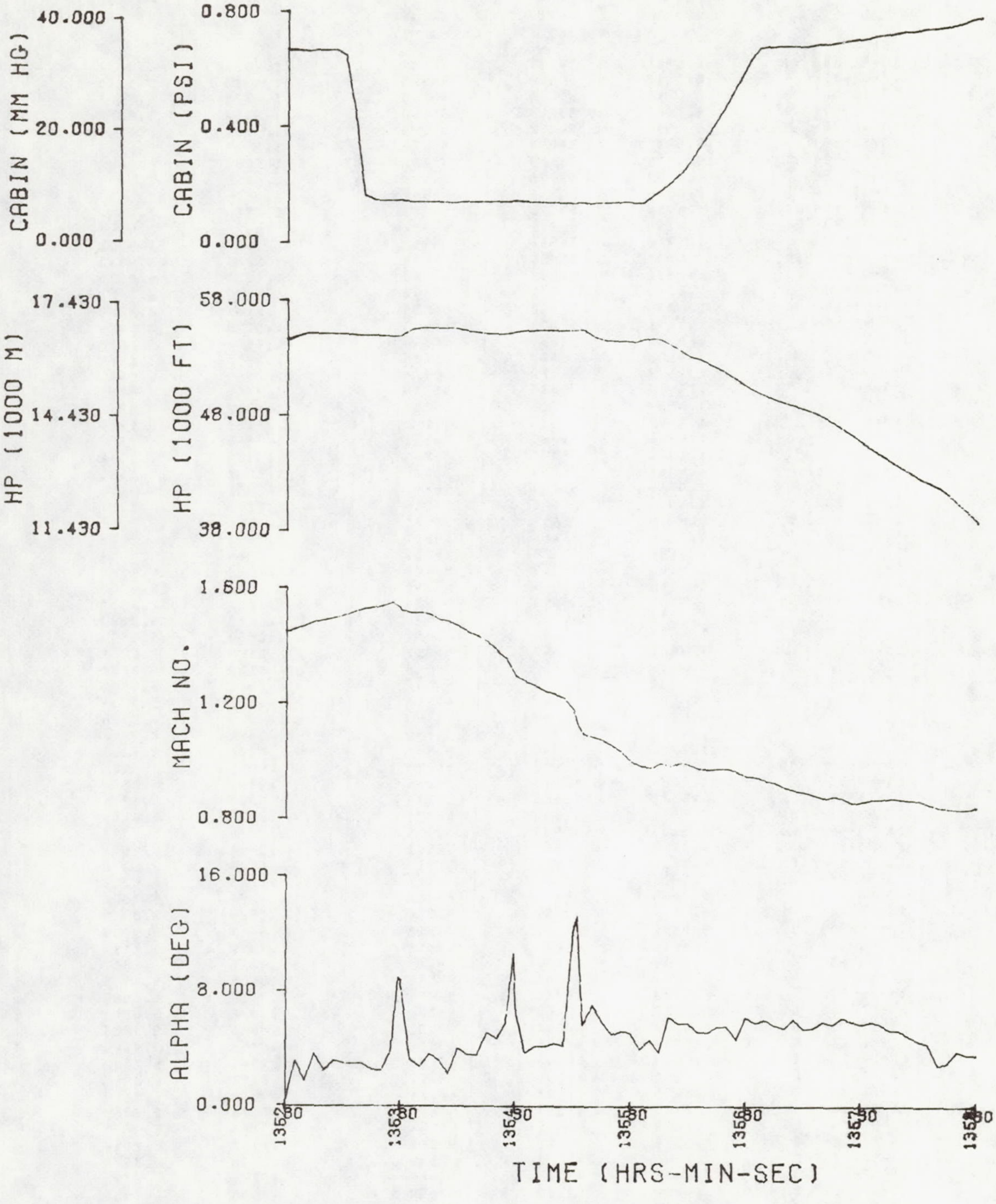

Figure 10. F-15 jerkin suit cabin depressurization test.

T A B L E 3. F-1 5 C A B I N A L T I T U D E (H C)

CABIN ALTITUDE DIFFERENTIAL BELOW AIRCRAFT ALTITUDE(HP-HC)

TIME CODE	CABIN (PSI)	HC (FEET)	HP-HC (FEET)
13:53:15- 0	1.4764	52712	2271
13:53:20- 0	1.4749	52733	2249
13:53:25- 0	1.4719	52775	2111
13:53:28-800	1.5107	52234	2755
13:53:30- 0	1.4636	52894	2209
13:53:35- 0	1.4314	53357	2251
13:53:40- 0	1.4336	53325	2374
13:53:45- 0	1.4201	53522	2121
13:53:50- 0	1.4448	53163	2531
13:53:55- 0	1.4006	53809	1907
13:54: 0- 0	1.4523	53055	2470
13:54: 5- 0	1.4559	53004	238[illegible]
13:54:10- 0	1.4559	53004	2263
13:54:15- 0	1.4409	53219	1923
13:54:20- 0	1.4746	52738	2413
13:54:25- 0	1.4701	52801	2448
13:54:29-200	1.4866	52569	2829
13:54:30- 0	1.4469	53133	2265
13:54:35- 0	1.4439	53176	2339
13:54:40- 0	1.4424	53179	2351
13:54:45- 0	1.4124	53635	1892
13:54:50- 0	1.4094	53679	1830
13:54:55- 0	1.4049	53746	1732
13:55: 0- 0	1.4019	53790	1726
13:55: 0-500	1.4386	53252	2282
13:55: 2-100	1.4371	53274	2312
13:55: 5- 0	1.4004	53812	1655
13:55:10- 0	1.4401	53231	1686
13:55:15- 0	1.4446	53166	1479
13:55:20- 0	1.4521	53058	1544
13:55:25- 0	1.4866	52569	2094
13:55:30- 0	1.4319	53349	116[illegible]
13:55:35- 0	1.4538	53034	1750

NOTE--CABIN (PSI) WAS TAKEN FROM TABLE 2.

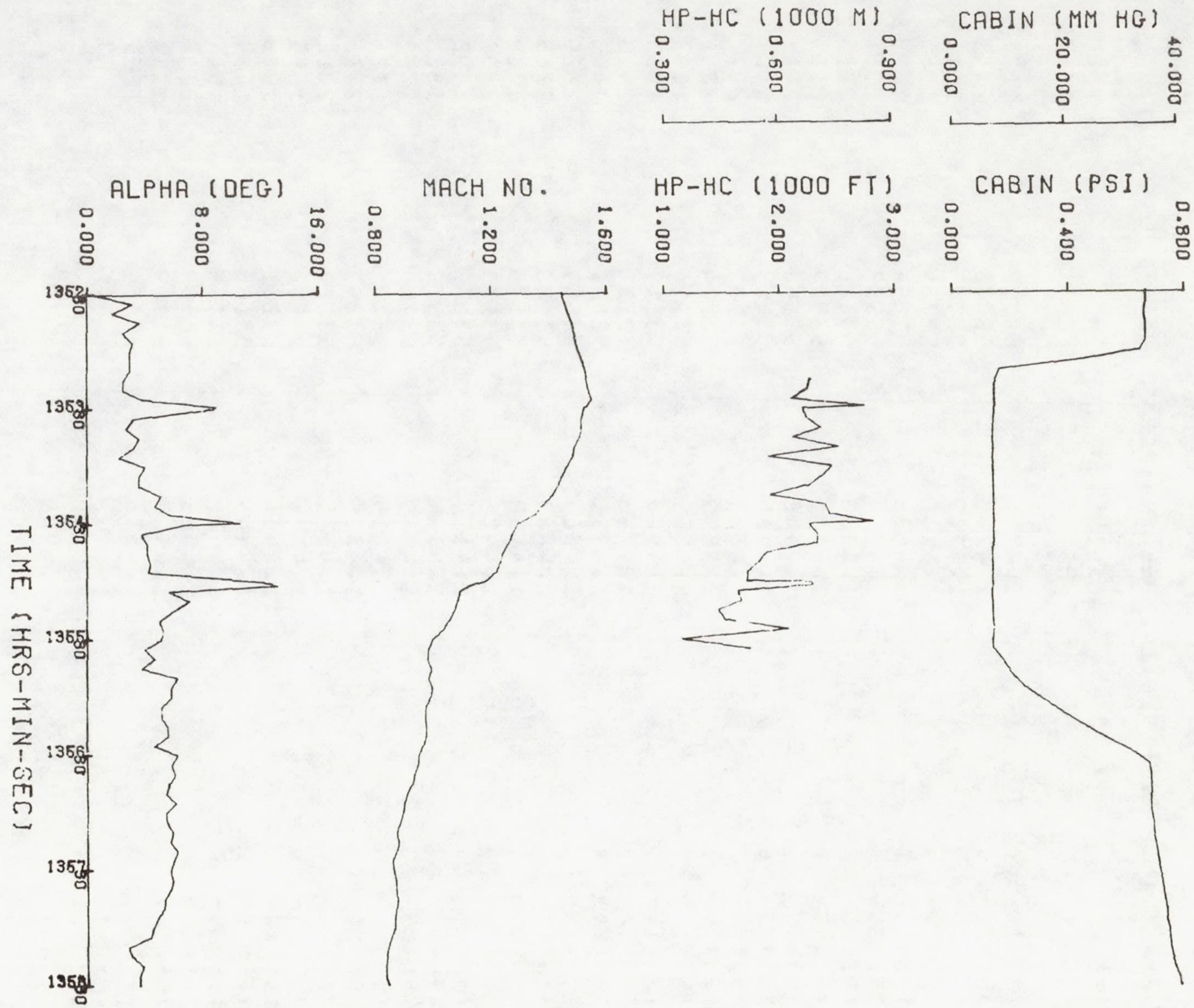

Figure 11. F-15 cabin altitude below aircraft altitude (HP-HC) during cabin decompression.

emergency descents) to replace the full pressure suit for protection of the pilot up to altitudes of 18,288 meters (60,000 feet).

CONCLUSIONS

Flight testing of a pressure jerkin at the Dryden Flight Research Center resulted in its adoption as the operational suit for emergency descents to replace the full pressure suit up to altitudes of 18,288 meters (60,000 feet). The jerkin provides protection for the pilot during emergency descents after cabin depressurization without having the disadvantages of a full pressure suit. Pilot effectiveness is greater because of the improved field of vision, improved hand and finger dexterity, and the ability to use a standard pilot helmet.

The pressure jerkin garment and anti-g trousers were preferred by the pilots over the combined partial pressure, anti-g and ventilated coverall garment, since the former can be donned at the aircraft and minimizes thermal buildup.

The Royal Air Force (RAF), oxygen mask with the tension chain harness did not slip down the pilots face under g-loading. The pilots at the Dryden Flight Research Center preferred this mask to those currently in use.

Cabin depressurization in the F-104 resulted in cabin pressure altitudes greater than the aircraft's pressure altitude. This is in contrast to the results of cabin depressurization in the F-15, which resulted in cabin altitudes less than the aircraft's altitude. Safety aspects therefore would favor the F-15 as the test aircraft because in cabin depressurizations the pilot would be exposed to lower cabin altitudes.

APPENDIX I - DESCRIPTION OF TEST EQUIPMENT

This appendix is a memorandum from the RAF Institute of Aviation Medicine describing two pressure jerkin assemblies and their associated equipment. The memorandum was written by the RAF on 9 September 1976, to document the equipment which was agreed upon by NASA/DFRC and RAF personnel for possible use in flight tests at DFRC. The memorandum also documents the RAF and RN experience with the pressure jerkin.

RAF PARTIAL PRESSURE ASSEMBLIES FOR USE IN TEST FLYING AT NASA FLIGHT RESEARCH CENTRE, EDWARDS CALIFORNIA

INTRODUCTION

1. Two integrated partial pressure high altitude protective assemblies were agreed as possible contenders for use in flight tests in F15 and F104 aircraft at the NASA Flight Research Centre, Edwards during the visit of personnel of the Centre to the RAF Institute of Aviation Medicine, 1 - 3 Sep 76. Both assemblies employ the RAF type P(Large)/Q (Small) pressure demand oronasal masks, counterpressure to the trunk and lower limbs and the type 324 miniaturised man mounted oxygen regulator. This regulator inflates the pressure clothing within 2 sec of an instantaneous decompression to a breathing pressure which increases linearly with fall of environmental pressure from 5 - 10 mm Hg at 40,000 feet to 68 - 72 mm Hg at 60,000 feet. Both assemblies will provide protection against hypoxia on rapid decompression to cabin altitudes up to 60,000 feet provided that descent is initiated within 1 minute. The subsequent rate of descent to below a cabin altitude of 40,000 feet should be at least 10,000 feet per minute (ie the assemblies provide protection for a total of 2 minutes above 50,000 feet and 3 minutes above 40,000 feet).

PRESSURE DEMAND MASK

2. The type P/Q mask must be attached by means of its chain suspension harness to the aircrew protective helmet in such a manner that the complete mask/helmet assembly is stable and that the mask will seal without significant leakage a pressure breathing of at least 70 mm Hg (at this pressure the outboard leakage is not to exceed 15 litre per minute).

TYPE 324 MINIATURE OXYGEN REGULATOR

3. The type 324 regulator provides both oxygen and oxygen diluted with air ('airmix') on demand with safety pressure (from ground level when 100% oxygen is selected and above 16,000 - 18,000 feet when airmix is selected) and pressure breathing to the schedule given in para 1 above. There is an oxygen pressure operated air shut off valve so that air cannot be drawn in through the regulator unless the oxygen supply pressure exceeds 35 Lb./sq.in. gauge. There is also a pressure-to-test facility. The nominal oxygen supply pressure for the regulator is 70 to 110 Lb./sq.in. gauge although it will function satisfactorily at supply pressures down to 50 Lb./sq.in. gauge. The regulator can therefore be supplied with main and emergency oxygen through the seat survival kit in both the F15 and the F104. The standard RAF type 324 regulator has been modified for use in the F15 and F104 by the removal of the standard pressure control line to the compensated outlet valve of the mask, the addition of a high flow capacity relief valve at its outlet and deletion of the secondary by-pass facility. The regulator will be mounted low on the front of the torso at a position to be decided by NASA.

PRESSURE CLOTHING AND CONNECTIONS

4. Two pressure clothing assemblies each with different merits have been agreed for the NASA task:

(1) Pressure jerkin and anti G trousers. The pressure jerkin applies counterpressure to the entire trunk. Its oxygen bladder is connected by a jerkin valve Mk 4 to the hose assembly between the outlet of the type 324 regulator and the type P/Q mask. The

pressure jerkin is worn as the outermost garment so that heat load can be minimised by delaying donning until the pilot is about to enter the cockpit and doffing the garment directly after flight. Counterpressure is applied to the lower limbs by standard RAF internal anti G trousers (Mk 6 or Mk 7). The trousers can either be inflated with oxygen by connecting the G-bladder into the oxygen hose between the outlet of the type 324 regulator and the jerkin connector or by a barometric anti G valve which responds both to +Gz and to fall of cabin pressure.

(2) Combined partial pressure, anti G and ventilated coverall Mk 2 (modified by removal of sleeves). Its oxygen bladder applies counterpressure to the whole of the trunk and to the lower limbs. It is inflated from the type 324 regulator through a jerkin valve Mk 9. The anti G bladder is inflated by a standard anti G valve and air (engine bleed air or cabin air) can be blown through the simple internal ventilation harness. The combined garment is worn directly over underclothes and has to be donned and doffed in the crewroom. The front sliding fastener can however be opened whilst on the ground to reduce the heat load imposed by the garment. The sleeves have been removed from the standard Mk 2 garment to reduce further the heat load.

5. The relative merits of the two pressure clothing assemblies relate to the heat load they impose and the ease with which it is possible to provide both high altitude and G protection. The simplest assembly which provides both high altitude and G protection and which can be used with the 70 Lb./sq.in. oxygen supply and the anti G valve fitted to the F15 and F104 is the combined partial pressure coverall (without sleeves). This assembly will however probably impose a greater heat load than the pressure jerkin and anti G trousers, especially on the ground. The pressure jerkin and anti G trouser assembly can be connected simply to the oxygen supplies in the F15 and F104 so as to provide high altitude protection but G protection is lost. The use of an RAF barometric anti G valve requires an airframe modification and in any case is unsatisfactory as then the assembly will not give altitude protection in the event of loss of cabin pressure due to engine flame out (which will also deprive the anti G valve of air). A shuttle valve (none available off the shelf although several designs have been used in the past in test flying in the UK) can be employed to allow the anti G trousers to be inflated by the standard anti G valve when exposed to +Gz and by the oxygen regulator on loss of cabin pressure at high altitude. An alternative and probably simpler method of providing high altitude and G protection in the pressure jerkin-anti G trouser assembly is to incorporate a second bladder in the anti G trousers. One G trouser bladder can be inflated by the anti G valve and the other by the oxygen regulator.

RAF/RN TRAINING EXPERIENCE

6. Well over 1000 RAF aircrew have been trained in the use of the standard type P/Q mask/pressure jerkin/anti G trouser assembly used in association with the panel mounted regulator Mk 21. These aircrew completed their training by undergoing a rapid decompression to a maximum altitude of 56,000 feet which was held for ½ minute

and followed by descent at 10,000 feet per minute to below 40,000 feet. Although in the first 500 aircrew trained approximately 5% failed to complete the entire altitude exposure after changes to the ground training procedures in the last 4 years all aircrew have successfully completed the prescribed altitude exposure to 56,000 feet. Some 200 RAF and RN aircrew have been exposed to an altitude of 60,000 feet for 1 minute followed by a descent at 10,000 feet per minute to below 40,000 feet whilst wearing the type P/Q mask and combined partial pressure, anti G and ventilated coverall Mk 2. Again, although in the initial stages of the programme some 5 - 8% of aircrew failed to complete this exposure all those exposed in the last 4 years have done so completely successfully.

J Ernsting

J ERNSTING
Group Captain
Deputy Director
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IAM/AEG/18/03
9 Sep 76

RAF INSTITUTE OF AVIATION MEDICINE
FARNBOROUGH, HANTS

APPENDIX II - JOINT EFFORT MEMORANDUM

FOR PRESSURE JERKIN EVALUATION

The USAF School of Aviation Medicine (SAM) and NASA Dryden Flight Research Center (DFRC) agreed to jointly evaluate the pressure jerkin. Appendix II is a memorandum by SAM and DFRC personnel outlining six coordinated efforts to be performed and the results obtained. The memorandum, which is not dated, lists Capt. Tom Smogur as the primary author.

JOINT TESTING OF THE RAF HIGH ALTITUDE PROTECTIVE ENSEMBLE

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ABSTRACT

In an effort to provide relatively nonencumbering "get me down" protection from altitudes above 50,000 feet, NASA's Dryden Flight Research Center and the USAF School of Aerospace Medicine joined in an effort to evaluate the suitability of a RAF high altitude protective assembly. The joint project consisted of six coordinated efforts: laboratory evaluation, orientation/training of NASA test pilots, quantification of aerodynamic suction effects on cockpit altitude, definition of protective envelope, suit/aircraft integration, and in-flight test and evaluation. The RAF Jerkin assembly was found to meet both the pilot's physiological and functional requirements.

INTRODUCTION

Full pressure suits have characteristically received only marginal acceptance among crewmembers of high performance aircraft. Impairment to the mobility, comfort and general effectiveness of the wearer preclude their application from all but clearly hazardous high-altitude reconnaisance or flight-test missions. Even on these missions their use often involves undesirable restrictions to the pilots' visibility, mobility, dexterity, and compromises mission effectiveness.

Many fighter aircraft in the USAF inventory are capable of sustained flight above 50,000 feet, and almost all can easily zoom or perform pop-up maneuvers to altitudes where, if the cabin pressurization were lost, the standard oxygen equipment would not provide safe get-me-down protection. Advancements in engine technology, such as engines capable of supersonic flight without the aid of afterburner, point the way to next generation aircraft cruising at altitudes requiring physiological protection which current USAF operational oxygen equipment cannot provide.

In an effort to provide "get me down" capability from flight above 50,000 feet NASA's Dryden Flight Research Center (NASA DFRC), Edwards AFB, Ca intends to adopt the relatively nonencumbering RAF partial pressure clothing for use in F-104 and F-15 aircraft. This equipment is currently being used for short term protection to 60,000 feet by the RAF. Since the USAF School of Aerospace Medicine (USAFSAM) is similarly interested in the development of fighter-compatible high altitude protective equipment, NASA DFRC requested joint participation in this effort. A Memorandum of Agreement was signed in June between NASA DFRC and USAFSAM formalizing respective responsibilities and the development plan under which the testing would be conducted. The Royal Air Force

Institute of Aviation Medicine (RAFIAM) agreed to supply the equipment and provide initial training to DFRC personnel. As the effort progressed, the Air Force Flight Test Center (AFFTC) Physiological Support Division's participation was requested to aid in pilot suit training and suit/aircraft integration.

OUTLINE OF EFFORTS

The equipment assembly tested included: a sleeveless Jerkin pressure vest, G-suit and an RAF P/Q oronasal mask. The program consisted of six coordinated efforts: (1) laboratory evaluation, (2) orientation/training of NASA test pilots, (3) quantification of aerodynamic suction effects on cockpit altitude, (4) definition of protective envelope, (5) suit/aircraft integration, and (6) in-flight test and evaluation.

(1) Laboratory Evaluation:

- (a) Configuration analysis
- (b) Bench tests
- (c) Subject training breathing 70 mmHg pressures at Ground Level.
- (d) Controlled ascents to 50,000 and 60,000 feet.
- (e) Rapid decompressions from 25,000 to 60,000 feet.

(2) NASA Test Pilot Training:

- (a) Coordination meeting
- (b) Ground level training
- (c) Controlled ascents
- (d) Rapid decompressions

(3) Quantification of Aerodynamic Suction Effects on Cockpit Altitude:

- (a) F-104 characterization
- (b) F-15 characterization

(4) Definition of Protective Envelope:

- (a) F-104 application
- (b) F-15 application

(5) Suit/Aircraft Integration:

- (a) F-104
- (b) F-15

(6) In-Flight Test and Evaluation:

- (a) Normal (pressurized) sorties
- (b) In-flight decompression/recovery (TF-104)

METHODS & RESULTS

Laboratory Evaluation: The ensemble was tested and the components were found to integrate into an effective assembly. Initial check-out found the suit regulator was not delivering sufficient pressure at altitude. After consultation with AFFTC's Physiological Support Division, the regulator was adjusted; the functional anomaly was most likely due to rough treatment during transit. The regulator functioned flawlessly throughout the remaining tests.

Ground level training was completed on three USAFSAM test subjects. All subjects remarked, at the end of the subsequent altitude chamber testing, that the ground level testing was more difficult and uncomfortable than using the RAF ensemble at altitude. However, they all agreed that familiarity and training with the assembly not only increased confidence, but also aided the user in achieving better protective effect from the ensemble.

The test subjects took three low pressure chamber flights to gain familiarity and confidence in the RAF Jerkin. The first was designed to assess the adequacy of equipment performance in the intermediate altitude envelope. The maximum altitude was 50M' with a maximum time above 40M' of two minutes. The second flight profile was similar to the first with the exception of the maximum altitude of 60M'. The third flight was a rapid decompression from 25M' to 60M' with one minute at 60M' prior to descent.

Subjects denitrogenated for one hour prior to all flights. Both heart rate and suit pressure data were recorded during all chamber runs. The data gathered was used for safety monitoring only, since the foregoing tests used a proven protective concept and were conducted within a well defined altitude envelope i.e., the RAF have conducted hundreds of training flights to the same altitudes with the Jerkin ensemble. Laboratory personnel chose to conduct additional chamber flights to assure subject/pilot preparedness, to facilitate full USAF documentation of RAF equipment used, and to develop an experience base for insuring optimum safety and test effectiveness.

The chamber flights were uneventful. There were no adverse physiological reactions. All subjects' ears were checked pre- and post-flight. The flight surgeon in attendance also checked for possible post exposure nitrogen bubble formation with a Doppler ultrasonic bubble detection device. Again subjects stated that there was a definite "training effect" and a resultant enhanced performance at altitude.

NASA Test Pilot Training: A coordination meeting was held at the Edwards Physiological Support Division on 18 July 1977. Representatives from all three participating organizations were present, and scheduling and tasking were worked out during this session.

Ground level pilot training with altitude chamber profiles identical to those used at USAFSAM were accomplished over a three day period.

Pilot comments were similar to the test subjects at Brooks. Both pilots felt that the Jerkin provided adequate physiological protection and excellent mobility at altitude. Both also stated that there was a definite training effect.

Quantification of Aerodynamic Suction Effects on Cabin Altitude: The NASA test team wearing full pressure suits took two seat F-104's to altitudes up to 60,000 feet with a deflated canopy seal to check out the aerodynamic (slipstream) effects on the cabin altitude. The results showed that effect was minimal and at no time was the cabin altitude higher than two thousand feet above the ambient flight level. An unexpected result was that the greater the Mach number, the less the deviation from ambient. Due to technical problems NASA was unable to make the characterization for the F-15.

Definition of Protective Envelope: A meeting was held in August 1977 at USAFSAM with representatives of all three participating organizations. Progress was discussed and the protective envelope maximum altitude for the Jerkin in-flight testing was defined as 60,000 feet providing descent is initiated in less than one minute following loss of cabin pressurization. In an operational scenario, a prebreathing period of at least 30 minutes was recommended to be accomplished prior to ascent through 18,000 feet.

Suit/Aircraft Integration: This was accomplished in early August by NASA and AFFTC personnel.

In-Flight Test and Evaluation: Flight testing was conducted in late August at DFRC. During these tests one pilot wore a standard (-6) full pressure suit while the other wore the Jerkin. The following was extracted from one of the pilots' flight notes, "No ear trouble or other physiological problems were encountered. Thermal buildup was considered slight compared to a full pressure suit. Lack of harrassment from a pressure suit was quite evident; it was a real pleasure to fly with normal gloves and a standard helmet." The in-flight testing is still in progress, but these comments have been typical of the in-flight results.

CONCLUDING COMMENT

The final results are not yet available, but it is the opinion of the joint test group (USAFSAM, NASA DFRC, AFFTC) that the RAF ensemble or equivalent would be the only currently available item that would be acceptable to tactical crews. The Jerkin ensemble appears to meet both the pilot's physiological and functional requirements.

The authors wish to thank the RAFIAM not only for the use of the Jerkin assembly, but for sharing the insights on the equipment gained through years of careful study. The success of this feasibility study was aided in great measure by the fine physiological and technical data provided by the IAM staff.

The voluntary informed consent of the subjects used in this research was obtained in accordance with AFR 80-33.

THOMAS G. SMOGUR, Capt, USAF, BSC: Tom Smogur is presently assigned to the Directorate of Research and Development of the headquarters Aerospace Medical Division. He holds a BS in Biology and Chemistry, has completed graduate work in physiology, and a MS in Systems Management from the University of Southern California. Capt. Smogur has been an Aerospace Physiologist since 1968. He had extensive experience with full and partial pressure suits while assigned to the Air Force Flight Test Center with the SR-71, U-2, F-111, F-4, F-15, F-16, and various NASA lifting bodies.

APPENDIX III - FLIGHT TEST EVALUATION

OF A PARTIAL PRESSURE SUIT

This appendix is a memorandum that summarizes the flight test results in the evaluation of the partial pressure suit. This memorandum, written by NASA/DFRC project pilot William H. Dana, dated January 5, 1978, identifies DFRC's need, equipment configuration, training, and testing for the evaluation of the pressure jerkin.

Figure 1 of this appendix refers to figure 1 in this report. Figures 2 and 3 refer to figures 5 and 6, respectively.

[To comply with NASA publication policy, the name of the anti-g suit garment manufacturer has been deleted. - Ed.]

USE OF RAF HIGH ALTITUDE PROTECTIVE SYSTEM AT DRYDEN FLIGHT RESEARCH CENTER

BACKGROUND

In the accomplishment of propulsion testing in F-15 #281 during early 1976, it became apparent that DFRC pilots were going to be confronted with frequent flights at altitudes between 50,000 and 60,000 feet. At that time the only high altitude protection equipment available to DFRC pilots was the AP/22S full pressure suit. While this is the best full pressure suit available, its use compromises pilot effectiveness in several areas. It requires bulky gloves that reduce hand and finger dexterity, it incorporates a helmet and neck ring that reduce pilot field of vision (particularly downward vision, as when trying to look at switches on the side consoles), and its cooling system in the F-15 is inadequate for ground operations, quite often leaving the pilot hot and fatigued prior to takeoff (after start, ground checks, and taxi).

One of the F-15 project pilots, Einar Enevoldson, had used a British partial pressure suit during an RAF exchange tour, and felt that it would be a much more suitable garment for use during F-15 flight tests to altitudes up to 60,000 feet.

In September 1976 Einar, Roger Barnicki, and I visited the RAF Institute of Aviation Medicine at Farnborough for the purpose of indoctrination in the use of the partial pressure equipment and to make arrangements for the acquisition of such equipment.

DESCRIPTION

Appendix I is a description of the RAF partial pressure equipment as configured by the RAF for use by DFRC. Components used in the jerkin/g suit configuration are shown in Figure 1. The British gear provides "get-down" protection only. Breathing pressures somewhat lower than required for continuous operation at 60,000 feet are sufficient to allow the pilot to function fully during a descent within the specified time. For this system, a maximum of one minute at 60,000 feet followed by descent to 40,000 feet at 10,000 feet per minute is specified. For all F-15 and F-104 operations, the emergency descent times are much less than the specified time limit.

DFRC elected to use the two-bladder g-suit option (P.5., Appendix I) to provide anti-g and altitude protection. The major asset of the two-bladder g-suit is that it allows use of the RAF gear in both the F-15 and the F-104 without any modification to either aircraft. DFRC procured the specially-made two-bladder g-suit from the [redacted] at nominal cost and it is indistinguishable from a standard g-suit except for the inclusion of an extra inlet hose (Figure 1).

Einar elected to bring back both a jerkin and a combined garment (P.4., Appendix I) for evaluation. I felt so strongly about the benefit of donning the equipment at the aircraft that I elected to use only the jerkin.

TRAINING

Einar and I spent three days at the Institute of Aviation Medicine learning to pressure breathe and experiencing a rapid decompression in the RAF gear to a pressure altitude of 60,000 feet. Should this training be desired by other pilots, it is now available at the USAF altitude chamber at Edwards AFB. Einar and I both used decompressions in the Edwards chamber for verification of flight hardware prior to flight test.

GROUND TEST

In order to get an independent evaluation of the RAF gear, and to achieve some domestic exposure to it, DFRC arranged for the USAF School of Aerospace Medicine, Brooks AFB, to chamber test all RAF equipment proposed for our use. All of these tests were completed successfully in mid-1977.

FLIGHT TEST

In order to gain confidence in the use of the jerkin during an aircraft decompression, Einar and I flew four flights in a two-seat F-104. In each case one of us was in the front seat in a full-pressure suit and the other in the rear in a jerkin. The first two decompressions were to a cabin altitude of 50,000 feet; the others to an altitude of 60,000. In every case the pilot in the jerkin flew the aircraft from before decompression through a simulated emergency descent to 20,000 feet, where the test was considered complete. There were absolutely no problems encountered during these flights and the jerkin is considered suitably demonstrated for use in DFRC aircraft.

In addition, one flight was flown in the F-104 and one in the F-15 in which the canopy seal was deflated and the aircraft then climbed and accelerated to 55,000 feet and Mach 1.6. This was to determine if suction around the canopy would reduce cabin pressure below ambient and thus reduce the aircraft altitude to which the jerkin provides demonstrated protection. In both cases the cabin altitude remained lower (the cabin pressure remained higher) than the aircraft altitude, and it was concluded that it is safe to use the RAF jerkin for altitude protection in both the F-15 and the F-104 up to 60,000 feet aircraft altitude.

The combined garment has not yet been flight tested. A demonstration comparable to that done with the jerkin will be done in 1978. The jerkin has not yet been used in the F-15 but this, also, should occur next year. Figure 2 illustrates the jerkin and associated equipment installed in an F-15 seat.

USER OBSERVATIONS

The RAF altitude protection equipment has met with almost total pilot satisfaction. Hand dexterity and pilot field of vision are the same as when wearing a flying suit. Mobility in the cockpit is unimpeded. Ease of donning is excellent. The only drawback to the use of the jerkin is that it covers up some of the skin normally available for cooling. The incremental pilot heat buildup incurred by use of the jerkin is judged to be about the same as the increment incurred by wearing a g-suit. Wearing both the g-suit and the jerkin is considerably warmer than wearing only a flying suit, but the heat buildup is not intolerable and is considered to be a small price to pay for the privilege of not wearing a full pressure suit.

An unexpected side benefit of our use of the RAF equipment has been the desirability and general suitability of the P/Q masks (Figure 3). They are comfortable and they incorporate a microphone cutout switch, not included in U.S. masks but desirable for use in two-place aircraft. But the real asset of the P/Q masks is their immobility on the face at high g's. Since they ride on top of the pilot's chin bone and are held firmly to the pilot's face by tension chains, there is no tendency for them to rotate down and under the pilot's chin during g loads. I have never used a U.S. mask that didn't end up under my chin after pulling a few g's. DFRC's very limited supply of P/Q masks has precluded their use except during flights using the jerkin, but we are presently trying to purchase more of them; if this procurement is successful I intend to use a P/Q mask for all my flying.

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Edwards, California
January 5, 1978

REFERENCE

1. National Oceanic and Atmospheric Administration; National Aeronautics and Space Administration: U.S. Standard Atmosphere 1976. NOAA - S/T 76-1562, October 1976.

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15. Supplementary Notes

16. Abstract

A partial pressure suit was evaluated during flight tests in an F-104 and F-15 as a protective garment for emergency descents. The garment was chosen to provide optimum dexterity for the pilot, which is not available in a full pressure suit, while protecting the pilot at altitudes up to 18,288 meters (60,000 feet) during a cabin decompression and subsequent aircraft descent.

The garment is an RAF pressure jerkin and modified anti-g suit combined with an RAF oronasal mask. The garment can be donned and doffed at the aircraft to minimize thermal buildup. The oronasal mask was favored by the pilots due to its immobility on the face during high g-loading.

During cabin decompressions in the F-104 and F-15, cabin pressure altitude was measured at various aircraft angles of attack, Mach numbers, and altitudes to determine the effect of the aerodynamic slipstream on the cabin altitude. The greatest difference for the F-104 was a cabin altitude of 518 meters (1700 feet) above the indicated altitude whereas for the F-15 the greatest difference was 840 meters (2755 feet) below the indicated altitude.

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